BUTTE COUNTY

GENERAL PLAN

SEISMIC SAFETY ELEMENT

ADOPTED MARCH 15, 1977

SEISMIC SAFETY ELEMENT

CONTENTS

TABLES

MAPS

SEISMIC SAFETY ELEMENT

A. GENERAL

1. State Requirements

Section 65302(f) of the California State Code requires each county to prepare a Seismic Safety Element as part of the County General Plan. This element consists of:

> "...an identification and appraisal of seismic hazards such as susceptibility to surface ruptures from faulting, to ground shaking, to ground failures, or to the effects of seismically induced waves such as tsunamis and seiches.

> "...an appraisal of mudslides, landslides, and slope stability as necessary geologic hazards that must be considered simultaneously with other hazards such as possible surface ruptures from faulting, ground shaking, ground failure, and seismically induced waves."

The General Plan Guidelines adopted by the California Council on Intergovernmental Relations in 1973 state that the identification of seismic hazards should include: (1) general structural geology and geologic history, (2) location of all active and potentially active faults, with evaluation regarding past displacement and the probability of future movement, (3) evaluation of slope stability and soil subject to liquefaction and differential subsidence, (4) assessment of the potential for occurrence and severity of damage in ground shaking and amplifying effects of unconsolidated materials, (5) identification of areas subject to seiches and tsunamis, and (6) maps identifying the location of the above characteristics.

2. Planning Relationships

The Seismic Safety Element provides information that relates directly to the preparation of the Land Use, Housing, Open Space, Circulation, and Safety elements. It is important to recognize, however, that the data available for this purpose is inherently incomplete.

Land use decisions must be made in the light of the very best information when public safety is the issue. Therefore, this element of the General Plan for Butte County carries with it the assumption that available data on seismic risk is described or referenced here, and that new information will be added as it becomes known.

The application of this information to specific land use decisions can only be made case by case. In many situations, the information here is only a starting point for the detailed geologic investigations that are warranted by the circumstances. These will ordinarily be undertaken by the sponsor of a project in preparing an environmental impact report or an engineering feasibility study.

3. Alquist-Priolo Special Studies Zones

The California Public Resources Code Division 2, Chapter 7.5, Sections 2621-2625, concerns the Alquist-Priolo Special Studies Zones Act. The purpose of the act is:

> "...to provide for the adoption and administration of zoning laws, ordinances, rules, and regulations by cities and counties in implementation of the general plan that is in effect in any city or county...to provide policies and criteria to assist cities, counties, and state agencies in the exercise

of their responsibility to provide for the public safety in hazardous fault zones."

Site specific geologic reports are required for local approval of new real estate developments and certain structures for human occupancy which are located in the Special Studies Zone. The act does not apply to any development or structure in existence prior to January 1, 1977.

B. OBJECTIVE

The basic objective of the Seismic Safety Element is to prescribe measures to reduce loss of life, injury, damage to property, and economic and social disruption resulting from earthquakes.

C. PHYSIOGRAPIC PROVINCES

Butte County includes portions of three major physiographic provinces. The western one-third of the County is in the Sacramento Valley province, which is underlain by sedimentary rocks 15,000 feet thick, with 100-200 feet of recent sediment overlying the rocks (Tertiary Formations). The eastern two-thirds of the County is in the Sierra Nevada province and is underlain by igneous and metamorphic rocks. The portion of the County near Jonesville and Inskip lies partly in the Cascade Range physiographic province. The Cascade Range province is represented by a chain of volcanic cones where there are extrusive volcanic flows and pyroclastic sediments along with mudflows of volcanic and pyroclastic origin.

1. Sacramento Valley Province

The Sacramento Valley is a nearly level alluvial plain, separated geologically from the San Joaquin Valley by a buried northeast-trending fault in the vicinity of Stockton.

On the north, the valley terminates at the Klamath Mountain foothills. The valley is drained by the Sacramento River, which passes through flood basins that include the Butte Basin west of Oroville. Both natural and man-made levies border the Sacramento River through much of the lowlands.

Recent alluvium underlying the greater part of the valley intermingles with numerous stream deposits of silt, sand, and gravel which were deposited by streams from the hills to the east. These recent deposits consist mainly of reddish, sandy clay and black humus topsoil overlying unconsolidated sand, silt, clay, and gravel. The valley alluvium deposits increase in thickness from east to west, ranging from only a few inches along the foothills to more than 200 feet near the Sacramento River. The ground-water table is commonly high (within 10 feet of the surface) throughout the lowlands.

Pleistocene deposits of poorly consolidated, deeply red stained gravel, sand, silt, and clay are found as terraces along many of the stream channels near the eastern edge of the valley. The terraces were apparently formed as ancient flood plains of the Feather River and other streams during glacial periods.

2. Sierra Nevada Province

The Sierra Nevada is a westward tilted fault block of great magnitude. The block has a high, multiple-fault scarp face on the east front and a more gentle, fault-bound west front which disappears under the sediments of the Sacramento Valley. The bedrock of the Sierra Nevada province consists commonly of Paleozoic and Mesozoic metasediments and volcanics intruded by a Mesozoic granitic batholith. The Sierra Nevada Mountains form the major portion of the eastern half of Butte County.

Along the western slope of the Sierra Nevada range, Tertiary sediments, volcanics, and isolated areas of upper Cretaceous sediments of the Sierra Nevada foothills dip westward beneath the Sacramento Valley. The Sierra Nevada Range terminates abruptly in the north where it disappears beneath the younger Cenozoic volcanic rocks of the Cascade Range. Highly metamorphosed sedimentary and igneous rocks lie along the west and northern edges of the Sierra Nevada.

In Butte County the western foothills of the Sierra Nevada gradually merge into the Sacramento Valley. The foothills are comprised commonly of younger Tertiary sediments, extrusive flows, volcanic mudflow material, and old alluvial sediments. One of the dominant features of the foothills is the Tuscan monocline, a flexing of surface rocks which trends northwest between Chico and Red Bluff. The average dip of the surface east of this line of flexure is 2-3 degrees. West of this line, the dip changes and averages from 5-9 degrees, continuing at this angle until the surface rock penetrates the valley alluvium. The Tuscan monocline is a linear feature similar to that of a fault.

3. Cascade Range Province

The Cascade Range extends from Washington to northern Butte County. Mount Lassen, one of the few active volcanos in the continental United States, lies within this province approximately 23 miles north of the County. Late Cenozoic extrusive volcanic rocks comprise the mass of the Cascades. In Butte County, these rocks overlie portions of the sediments of the Sacramento Valley and the rock of the Sierra Nevada.

D. GENERAL GEOLOGY

The foothills and mountains of the Sierra Nevada and the Sacramento Valley are the result of a complex geologic history, some aspects of which are unclear even now.

The old bedrock, or metamorphic base rock, series of the Sierra Nevada has been subjected to an intense deformation resulting in dynamically metamorphosed rocks. Intense folding and faulting have produced an area of steep, commonly eastwardly dipping, northwesterly striking bedrock series through the center of the Sierra Nevada. This bedrock series is bound on the east and west by zones of active and potentially active faults.

In the eastern portion of the County, granite has intruded into the older metamorphic bedrock. These intrusives may extend to the west under the metamorphics at a relatively shallow depth. Contact between the granitic intrusives and metamorphics is in many cases marked by seismic evidence which indicates faulting may be continuing today.

On the west, the sediment of the Sacramento Valley overlaps the rocks of the Sierra Nevada foothills. These sediments, for the most part, are relatively flat and dip gently west to southwest with only minor faulting and folding parallel to the structural trend of the valley and the Sierra Nevada range.

E. SEISMIC HISTORY AND FAULTING

Butte County and the surrounding area are located on the western portion of a faulted and downwarped series of ancient metamorphic rocks of the Western Sierra Nevada Mountain Range. Granitic rocks associated with Mesozoic thrust faulting are located in the eastern portion of the County. In the western portion of the County, gently folded younger and sometimes faulted sediments of the Sacramento Valley overlie older metamorphic rocks similar to those of the Sierra Nevada. The strategraphic and structural trend of metamorphic rocks is generally northward with steeply dipping

bedding in most places. The formations and geologic structure of the County appear to be controlled or strongly modified by Cenozoic faults extending along the western portion of the Sierra Nevada Mountains and trending north-northwest along with the Big Bend, Camel Peak, Dogwood Peak, Rich Bar, and Melones faults, most of which lie to the north and east of Butte County in the area of granitic intrusions (see Map II-1). Most Sierra Nevada faults are a combination of strike slip and thrust movements. (Bailey, Geology of Northern California, California Division of Mines and Geology.)

Movement on the Cleveland Hill fault on 1 August 1975 was apparently the result of crustal strain developed in the foothill shear zone. The Cleveland Hill fault, located about 6 miles southeast of Oroville, trends north-northwest and is approximately 10 miles long. It is presently the only known active fault within Butte County. (Sherburne and Hauge, Oroville, California Earthquake, 1 August 1975, California Division of Mines and Geology.)

In the northwest corner of Butte County near Chico there are a series of short, north-northwest-trending faults similar to the Cleveland Hill fault. These faults appear to be an extension of the Bear Mountain Fault or Foothills Shear Zone (see Map II-1). Minor seismic activity has occurred in the area of these short faults; however, other geologic evidence indicates these faults are not active.

Approximately 5 miles west of Butte County there is a north-trending fault system known as the Willows fault (see Map II-1). This fault is approximately 40 miles long and displaces Cretaceous sediment in the Sacramento Valley. It does not appear to displace surface sediment and has been mapped principally by geophysical methods. However, there have been enough historical seismic events in the vicinity of

this fault to conclude that it should be considered potentially active. (Jennings, Fault Map of California, California Division of Mines and Geology.)

The Coast Range Mountains west of Butte County have a geologically complex history. A major complicating factor is the San Andreas fault, located on the western boundary of the Coast Range province. Although the existence of this fault has been well known since it was established as a source of earthquakes in 1838, 1857, 1901, and 1906, it has only been in the last 15 to 25 years that geologic evidence has been sufficient to fully document its importance. It is now well known that the San Andreas, and the faults related to it,is not only a major source of earthquakes but is the contact of one of the six major geologic plates of the earth's crust. The San Andreas and the related faults have a major impact on the seismic safety of Butte County. (Jennings, Fault Map of California, California Division of Mines and Geology, and Bailey, Geology of Northern California, California Division of Mines and Geology.)

F. POSSIBLE EARTHQUAKE SOURCES

The historic earthquakes of California have usually originated along faults which existed prior to the earthquake. An active fault is generally considered any fault which has undergone displacement of sufficient geologic recency to suggest that there is a potential for displacement in the reasonably near future. In general engineering practice, a fault is considered active if there is displacement within Holocene deposits regardless of datable evidence.

Faults are classified as potentially active based upon historic, geologic, and seismologic evidence. Historic evidence may include manuscripts, news accounts, personal diaries, and books which describe past earthquakes. Geologic

evidence of potentially active faulting may include displacement of geologically young formations. Accurately determined earthquake epicenters, which can be assigned to individual faults with a high degree of confidence, constitute seimologic evidence suggestive of possible fault activity. (Krinitzsky, State of the Art of Assessing Earthquake Hazards in the United States, U. S. Army Engineers Waterways Experiment Station.)

Those faults having historical or recent geologic activity are classified as active; faults located in areas of historical seismic activity are classified as potentially active; and all other faults are classified as potential, activity unknown.

1. Active Faults

a. Cleveland Hill Fault

The only known active fault in Butte County is the Cleveland Hill fault, where activity on 1 August 1975 resulted in the Oroville earthquake. This earthquake has a Richter magnitude of 5.7 and resulted in about 2.2 miles of surface cracking along the western flank of Cleveland Hill. Reports by the California Division of Mines and Geology indicate that the ground motion at Gridley, which is located on valley sediment, was approximately 0.1 times acceleration of gravity. Similar motion was experienced in Oroville, and considerable structural damage occurred. The earthquake was felt in Chico, but there was no recorded damage. Fault movement was both normal and strike-slip. Studies of lineaments from Skylab photography, the earthquake focal coordinate plane, and topography indicate that this fault could have a length of 11 to 15 miles with a maximum credible earthquake of 6.5 to 6.7 Richter and a maximum bedrock acceleration 1 to 2 miles

from the fault of 0.45 to 0.65g (Greensfelder, A Map of Maximum Bedrock Accelerations From Earthquakes in California). Historically, other earthquakes have occurred in Butte County; however, none of these have resulted in recorded strucutral damage or ground motion as great as that of the 1975 Oroville earthquake. (Sherburne and Hauge, Oroville, California Earthquake, August 1, 1975, California Division of Mines and Geology.)

The presence of Oroville Dam and Lake Oroville in proximity to the Cleveland Hill fault may affect seismic activity along the fault. Some researchers theorize that earthquakes can be caused by the weight of a dam and the water behind it and by the lubrication of fault surfaces by water seeping from the reservoir. A relationship between Lake Oroville, the Cleveland Hill fault, and recent earthquakes may exist, but additional study is needed to determine its nature. Because of the speculative nature of current data on the subject, no such relationship was assumed in the development of policies on seismic hazards.

On January 1, 1977, a 4-1/2 mile long portion of the Cleveland Hill fault trace was declared a Special Study Zone by the State of California. The location of the Cleveland Hill fault and the Special Studies Zone is shown in Map II-1. Copies of the Official Map showing the location of the zone and requirements pertaining to the zone are on file at the Butte County Planning Department.

b. Midland-Sweitzer Fault

The 80 mile-long Midland-Sweitzer fault is located approximately 40 miles south-southwest of Butte County. This fault is considered active and has caused historic earthquakes of Richter magnitudes between 6 to 6.9.

Greensfelder (1973) estimated that the Midland-Sweitzer fault is capable of producing a magnitude 7.0 earthquake, probably based on the occurrence of two strong earthquakes in the area in 1892. The first of these earthquakes had an intensity of X on the Modified Mercalli scale in Solano County, and was felt as far away as western Nevada. The second earthquake occurred in the Winters area and had an intensity of Modified Mercalli IX . Damage was reported as far away as Grass Valley and Lodi. There is some speculation as to the exact location of the earthquake epicenters and some question if they actually occurred on the Midland-Sweitzer fault. However, since the 1892 earthquakes originated on a fault within this same general area and at a considerable distance from Butte County, the precise identity of the fault is not significant at this time. (Bailey, Seismic Safety Information, and Jennings, Fault Map of California, California Division of Mines and Geology.)

c. San Andreas Fault Zone (North Section)

The San Andreas fault is one of the most active in California. The fault is more than 650 miles long and extends from Shelter Cove to the Salton Sea. At its nearest point, the San Andreas fault is located approximately 95 miles west of Butte County. Geologic evidence indicates that the total strike-slip movement along this fault has been on the order of 450 miles and could possibly be as great as 750 miles. Significant historic earthquakes with surface rupture occurred along the San Andreas Zone in 1838, 1857, 1901, 1906, 1922, 1934, and 1966. The effects of the 1906 earthquake, measured at 8.3 Richter, were described in the State Earthquake Investigation Commission report, California Earthquake of April 18, 1906. That report indicates that the Modified Mercalli intensity of the 1906 earthquake was between V and VI in western Butte County and IV to V in eastern Butte County.

d. Hayward-Calaveras Fault Complex

The Hayward-Calaveras fault complex is considered by the Division of Mines and Geology to be a branch of the San Andreas fault. The most active portion of the Hayward fault is approximately 45 miles long and extends from San Pablo Bay to the Warm Springs district of Fremont. It apparently joins the Calaveras fault in the vicinity of San Jose. Extensive ground rupture occurred along this fault during major earthquakes in 1836 and again in 1868. Near the fault, these earthquakes had a reported maximum Modified Mercalli intensity of IX to X. Widespread damage was reported. The Hayward fault has also been the focus of other damaging earthquakes. Historical accounts do not describe the effects of these earthquakes in the vicinity of Butte County; however, the 1868 earthquake is reported to have caused strong fluctuations in the water level in the Sacramento River near Sacramento and in a slough near Stockton.

Strong earthquakes have occurred along the Calaveras fault, an apparent continuation of the Hayward and San Andreas fault system. The strongest recorded earthquake attributed to the Calaveras fault was in 1861 when there was a Modified Mercalli intensity of VIII near the fault.

e. Russell Valley Fault

The Russell Valley fault system is located in the easternmost Sierra Nevada frontal fault system. The fault trends north-northeast and is approximately 50 miles east of Butte County. Movement on this fault apparently resulted in the 1966 Truckee earthquake. The reported magnitude of the 1966 earthquake ranged between 5.4 Richter (U.S. Coast and Geodetic Survey) and 6.5 Richter (California Institute of Technology). The surface rupture of the fault was reported

to be approximately 10 miles long. The earthquake caused minor damage to dams, bridges, structures, and water wells in the Truckee area. (Kachadoorian, et. al., Effects of the Truckee, California Earthquake of September 12, 1966, U.S. Geological Survey.) The earthquake was felt in Butte County, but no damage was reported. The Modified Mercalli intensity of the 1966 earthquake ranged from VIII near Truckee to IV near Oroville.

f. Last Chance-Honey Lake Fault Zones

The Last Chance-Honey Lake fault zones are approximately 100 miles long and trend north-northwest along the California-Nevada border. These faults are apparently active and have resulted in earthquakes ranging between 5 and 5.9 Richter.

2. Potentially Active Faults

Potentially active faults which could result in significant ground motion in Butte County are shown in Map II-1. These include the Foothills shear zone, Sutter's Butte faults, Willows fault, Dunnigan fault, Coast Range thrust zone, Big Bend fault zone, Camel's Peak fault, Melones-Dogwood Peak faults and the Hawkins Valley fault. All of these faults should be considered potentially active due to geologic, historic, or seismic data. Other potentially active faults may also exist within the County.

G. FAULT ZONE EVALUATION

Regional geologic investigations usually uncover only the major faults of an area. Small faults can be easily misread unless they have been previously mapped or outcrop at the surface. To account for small active faults that may exist within an area, the concept of a "floating earthquake" is

suggested by Krinitzsky (State of the Art for Assessing Earthquake Hazards in the United States). A "floating earthquake" is an earthquake with a specified maximum magnitude that may occur anywhere at any time. This magnitude is selected in relation to the highest recorded seismic event in the area. Based upon this concept and the brief seismic history available for Butte County, it appears a "floating earthquake" with a magnitude of 6 to 6.5 Richter could be assumed for central and eastern Butte County and 6.0 Richter for western Butte County.

Table 1 contains an evaluation of the estimated seismic effects in Butte County from earthquake activity in the fault zones discussed above. The principal regional sources of ground shaking in Butte County are probably the Hayward-Calaveras faults, the San Andreas fault, the Midland-Sweitzer fault, the Last Chance-Honey Lake fault zones, and small unmapped faults at scattered locations in the foothills and mountains of Butte County and the surrounding area. The Hayward-Calaveras and San Andreas faults have recurrence intervals such that seismic activity of magnitude 7 and 8 can be anticipated every 100 to 500 years. However, the long distance of these fault systems from Butte County should attenuate the ground motion and produce only moderate-intensity ground shaking in the County.

The recurrence interval of earthquakes on the Midland-Sweitzer fault is not documented. However, large magnitude earthquakes generated by this fault can be anticipated and could result in moderate to intense ground shaking in the County. The degree of ground shaking can be expected to vary with the type of soil; however, a Modified Mercalli intensity of VIII could be expected in much of Butte County.

Table 1. FAULT ZONE EVALUATION

Faults	Maximum Earthquake (Richter Magnitude) Credible*	Historic	Estimated Modified Mercalli Intensity in County Maximum	Average	Estimated Bedrock Acceleration in County Maximum	Average	Distance From County Boundary	Remarks
Cleveland Hill 10 Miles Long - Strike Slip/Normal	6.4	5.7	VIII	VII	0.45-0.6g	± 0.1g	In County	Active Fault
Midland - Sweitzer 80 Miles Long - Strike Slip	7.7	6.0-6.9	VIII-IX	VIII	0.1-0.2g	± 0.1-0.07g	40 Miles South-Southwest	Active Fault
Hayward - Calaveras ± 160 Miles Long - Strike Slip	7.6	± 7.0	VII	VI	0.03-0.1g	± 0.05g	± 70 Miles Southwest	Active Fault
San Andreas Fault Zone, N. Section ± 200 Miles Long - Strike Slip	8.3	8.3	VII	VI-VII	0.05g	± 0.04g	± 95 Miles Southwest	Active Fault
Last Chance - Honey Lake Est. 100 Miles Long	7.8	5.0-5.9	VIII	VII	0.1-0.2g	± 0.1g	± 50 Miles East	Active Fault
Russell Valley 10 Miles Long	6.5	6.5	VII	VI	0.06g	0.04g	50 Miles East	Active Fault
Foothills Shear Zone ± 40 Miles Long - Extends S. of Oroville	7.3	5.7	IX	VIII	0.6-0.9g	0.25-0.4g	Extends Into South County	Potentially Active
Willows ± 40 Miles Long	7.3	5.0-5.9	VIII	VII-VIII	0.4-0.6g	0.15-0.25g	± 5 Miles West	Potentially Active
Unnamed Fault Near Dunnigan ± 13 Miles Long	6.7	4.0-4.9	VIII	VI	0.05-0.15g	± 0.1g	± 30 Miles South	Potentially Active
Sutters Butte 6 Small Faults, 2-4 Miles Long	5.4-5.8	4.0-4.9	VI	V-VI	0.45-0.6g	± 0.2g	5-8 Miles South	Potentially Active
Coast Range Thrust Zone ± 200 Miles Long	8.25	4.0-4.9	IX-X	VIII	0.2-0.25g	0.1-0.12g	± 35 Miles West	Potentially Active
Big Bend Fault Zone ± 30 Miles Long	7.1	± 6.0 ?	IX-X	VIII-IX	0.5-0.8g	0.2-0.3g	In County	Potentially Active
Camels Peak ± 32 Miles Long	7.1	± 6.0 ?	IX-X	VIII-IX	0.5-0.8g	0.2-0.3g	Borders County	Potentially Active
Melones - Dogwood Peak ± 200 Miles Long	8.3	6.0	X-XII	IX-X	0.5-0.55g	0.15 ±	7-12 Miles East	Potentially Active
Hawkins Valley ± 70 Miles Long	7.6	6.0	IX	VIII	0.2-0.3g	0.15-0.2g	± 25 Miles East	Potentially Active

*See Appendix B for definition.

SOURCES: Greensfelder, Roger. 1972. *Maximum Expected Bedrock Accelerations from Earthquakes in California*, California Division of Mines and Geology.

Housner, G. W. 1955. Intensity of Earthquake Ground Shaking Near the Causative Fault. *Proceedings, 3rd World Conference on Earthquake Engineering, New Zealand*, Volume 1.

Howell, B. F., and Schultz, T. R. 1975. *Attenuation of Modified Mercalli Intensity with Distance from the Epicenter. Bulletin of the Seismological Society of America*, Vol. 65, No. 3, pp. 651-665.

Jenkins, O. P. 1962. *Geologic Map of California Chico Sheet*, California Division of Mines and Geology.

Jennings, Charles. 1975. *Fault Map of California*, California Division of Mines and Geology.

Schnabel, P. B., and Seed, H.B. July 1972. *Accelerations in Rock for Earthquakes in Western United States*, Earthquake Engineering Research Center, Report No. EERC 72-2.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, National Geophysical and Solar-Terrestrial Data Center, *Earthquake Data File*.

The recurrence interval of the Last Chance-Honey Lake fault zones is also not known. Ground shaking from these faults could vary from moderate to severe depending upon the types of soil in the area. The maximum credible earthquake in this fault zone is considered to be 7.8 Richter and could result in slight to moderate ground motion in Butte County.

Local earthquakes could result from movement on small faults similar to those of the Cleveland Hill fault. Geologic and seismic data indicate that small faults can exist throughout the foothills and mountains of Butte County. Assuming these small faults exist, and applying the "floating earthquake" concept, earthquakes could result in moderate to severe ground shaking similar to the ground shaking from the 1975 Oroville earthquake.

H. PREDICTED EFFECTS OF EARTHQUAKES

Large earthquakes are historically associated with surface ruptures localized along the main surface traces of strike-slip or thrust faults. Geologic data indicates the general displacement of the ground surface along a fault in Butte County may be horizontal along with some vertical movement. The break pattern is typically expressed by an echelon pattern of ground fractures that trend obliquely to the overall trace of the fault (this was observed at the Cleveland Hill fault in 1975). The fractures normally displace from a few inches to several feet, and the surface zone of major faults ranges in width from a few feet to several hundred feet or more.

Based upon geologic evidence and seismicity data, the estimated length of surface rupture for a typical Butte County fault may range from 6 to 25 miles. Locally, branch faults may also move, but movement on these lesser faults would be much more difficult to predict.

There is insufficient historical, geologic, and seismological data available to make a realistic estimate of the ground motion resulting from potentially active faults.

1. Ground Shaking

The character of ground shaking from a postulated earthquake is dependent on many factors. Most important is the character of the earthquake source (type of offset, magnitude, location, size of rupture, and stress drop). A second important factor is the distance from the associated rupture surface or earthquake to the area affected by the earthquake. The third important factor is the type of local geologic material. (Housner, Strong Ground Motion in Earthquake Engineering.)

To predict ground shaking in Butte County the first step is to estimate the bedrock motion at various locations in the County. The bedrock shaking amplitude for Butte County was approximated by using data proposed by Greensfelder for the continuation of bedrock motion versus distances from the fault. An essential consideration is the effect of geological conditions in the near surface amplification of the shock waves as they travel up through the layered rock and soil.

There are not enough geologic and seismic data available in Butte County to accurately estimate seismic or ground response at a particular site. Therefore, estimates are based upon data obtained from other localities in California. The anticipated maximum ground shaking intensity across all of Butte County is VIII on the Modified Mercalli scale; however, the intensity could vary locally from VII to IX, depending on the type and location of the fault (see Table 1).

2. Liquefaction

Liquefaction is defined as the transformation of a granular material from a solid state into a liquified state as a consequence of increased pore-water pressure (Youd, Liquefaction, Flow, and Associated Ground Failure). Liquefaction occurs when there is a sudden but temporary increase in the fluid pressure between the soil grains caused when the weight of the overlying soil or structure is temporarily supported by the water and not the soil grains.

The method commonly used for estimating liquefaction potential is based upon the Simplified Procedure for Evaluating Soil Liquefaction Potential, by Seed and Idriss, Journal of Soil Mechanics and Foundations Division, (ASCE 1971). This procedure was developed for clean sandy soils with relative densities less than 80 percent deposited in relatively level areas. Because the slope of the alluvial plains surrounding the Sacramento Valley is small, this method can be applied to most of the valley area. It cannot, however, be applied to sloping ground or mountainous terrain.

Using assumed soil parameters and a moderate intensity earthquake, it is concluded that granular soils with relative densities less than 65 percent that are located beneath the free-water surface have a high potential for liquefaction during moderate or strong ground shaking. The liquefaction potential of the Sacramento Valley can be generally summarized as follows:

- Clean, granular sediment (particularly sands) below the water table with a relative density of less than 65 percent should be considered to have high liquefaction potential during moderate or strong ground motion.

- Clean, granular sediment with relative densities greater than 90 percent should have low liquefaction potential even in strong ground motion.

- Clean, granular sediment with relative densities between 65 to 90 percent should have moderate liquefaction potential depending upon intensity and duration of the ground shaking, site conditions, and the textural properties of the sediments.

Map II-2 delineates zones estimated to have low, moderate, or high liquefaction potential. The zones were derived from geologic investigations of the unconsolidated sediments of the Sacramento Valley. The liquefaction potential of granular layers was estimated from the available literature at the University of California Earthquake Engineering Research Center regarding relative density, water table, lithology, and seismicity.

Areas paralleling the Sacramento River containing clean sand layers were estimated to have a generally high liquefaction potential. Granular layers underlying the most of the Sacramento Valley have a slightly higher relative density and are thought to have a somewhat lower liquefaction potential and are classed as moderate risk. Clean layers of granular material of Pleistocene or older age are of even higher relative density and therefore are esitmated to have a low potential for liquefaction. Areas of bedrock throughout the Sierra Nevada are assumed to have no liquefaction potential; however, localized areas of valley fill consisting of Recent sand and gravel alluvium can have moderate to high liquefaction potential.

The zones delineated in this investigation as having liquefaction potential indicate only general areas in which the liquefaction may occur in clean, saturated, granular layers. Current data are not adequate for accurate mapping and do not provide an indication of the extent of ground failure that might follow liquefaction. The estimated liquefaction potential of each of these zones is based upon limited soil and geologic data generalized to include an entire map unit. Therefore, Map II-2 must be considered approximate and invalid for direct determination of liquefaction potential on a specific site. The map does, however, indicate areas where the probability of liquefaction exists during a major earthquake.

3. Seiches

A seiche is a periodic oscillation of a body of water such as a river, lake, harbor, or bay resulting from seismic or other causes. The period of the oscillation may vary from a few minutes to several hours. Seiche effects have not been recorded in any of the reservoirs in Butte County that are within the jurisdiction of the State of California Division of Safety of Dams.

The assessment of hazards from water waves is very difficult due to the limited historical data and geological knowledge of the areas surrounding the reservoirs in Butte County. Crude methods are presently available for assessing the amplifying effect of the coastal topography and for mapping potential areas of inundation from dam and reservoir failure or from landslide-generated waves that may overtop a dam crest. It appears, however, that water waves resulting from a large landslide are a much greater seismic hazard in Butte County than a seiche. According to the U.S. Geological Survey, the near failure of the Van Norman Reservoir was due

I. POLICIES

Table 2 summarizes the findings discussed above, states the County's policy in response to the findings, and outlines implementation measures.

Table 2. SEISMIC SAFETY ELEMENT

FINDINGS	POLICY	IMPLEMENTATION
1. Butte County is in an area of known faults and recent seismic activity.	1. Inform the public of current estimates of seismic hazard in all parts of the County.	1. Approve and publish this plan element. Keep the information up-to-date.
2. The only known active fault in Butte County is the Cleveland Hill fault near Oroville. A number of faults in or near the County should be considered potentially active. The proximity of the San Andreas fault system is generally significant in evaluating seismic risk in the County.	2. Take into account all known seismic information in making land use decisions. Avoid locating schools, hospitals, public buildings, and similar uses in known active fault areas.	2a. Consider the most recent information on seismic hazard in all zoning and subdivision decisions.
		b. Require appropriate detailed seismic investigations for all public and private projects in locations of known active fault areas.
3. The area around the Cleveland Hill fault has been designated as a Special Studies Zone under the Alquist-Priolo Act, effective January 1, 1977. (Chapter 7.5, Division 2, California Code)	3. Follow the policies and criteria established by the State Mining and Geology Board within the Special Studies Zone.	3. Exercise approval authority with respect to all real estate development and structures for human occupancy within the Special Studies Zone, as provided by State Law.
4. Portions of the Sacramento Valley have a generally high potential for liquefaction during a major earthquake.	4. Consider liquefaction potential in making land use decisions.	4. Require appropriate design of structures susceptible to the effects of liquefaction.

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U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service National Geophysical and Solar-Terrestrial Data Center, EARTHQUAKE DATA FILE
California Division of Mines and Geology, 1 Jan. 1977 SPECIAL STUDIES ZONES Bangor Quadrangle Official Map.
RECORDED EARTHQUAKES
Epicenter
Richter Magnitudes
0.1 to 3.9
4.0 to 4.9
5.0 to 5.9
6.0 & Greater
FAULTS
Active
Activity Unknown
Inferred
Possible (Lineation)
Concealed
OROVILLE August 1-8, 1975
After Shock Epicenter Region
Notes:
All of Butte County is in the Moderate Earthquake Intensity Zone VIII
Official Map of Special Studies Zone is on File at Butte County Planning Commission
JONESVILLE
BUTTE MEADOWS
INSKIP
Rich Bar Fault
Melones Fault
Tuscan Monocline
COHASSET
STIRLING CITY
FOREST RANCH
DE SABLA
RICHARDSON SPRINGS
MAGALIA
Camel Peak Fault
Dogwood Peak Fault
PULGA
NORD
PARADISE
CHICO
JARBO GAP
Big Bend
Fault
BRUSH CREEK
DAYTON
DURHAM
BUTTE COLLEGE
PENTZ
CHEROKEE
BERRY CREEK
FEATHER FALLS
NELSON
Foothills
Willows Fault
RICHVALE
THERMALITO
OROVILLE
FORBESTOWN
CLIPPER MILLS
HURLETON
PALERMO
WYANDOTTE
BIGGS
E. BIGGS
Zone
Cleveland Hills Fault Special Studies Zone
BANGOR
GRIDLEY
EAST GRIDLEY
HONCUT
BUTTE
EARTHQUAKE & FAULT ACTIVITY
SEISMIC SAFETY ELEMENT
BUTTE COUNTY GENERAL PLAN
PLANNING DEPARTMENT
REVISIONS
MAP II-1

Sources:

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Zone		Liquefaction Potential of Granular Sediments
(shaded)	Recent Sacramento Valley Sediments Bordering River-Alluvium	GENERALLY HIGH
2	Recent Valley Sediments Alluvium	GENERALLY MODERATE, LOCALLY HIGH where loose clean granular layers are present.
3	Pleistocene Alluvium and Bedrock	GENERALLY LOW except along stream channels where it may be LOCALLY HIGH in recent alluvium.

LIQUEFACTION POTENTIAL

SEISMIC SAFETY ELEMENT
BUTTE COUNTY GENERAL PLAN

PLANNING DEPARTMENT

MAP II-2

Appendix
SEISMIC SAFETY-SUPPORT DATA

CONTENTS

TABLES

FIGURES

DEFINITIONS

ACCELERATIONS (BEDROCK & GROUND) - The forces resulting from seismic waves traveling through the crust of the earth measured as a fraction times the force of gravity (example 0.15g). Maximum accelerations are generally higher for large magnitude earthquakes and for any given earthquake the acceleration forces decrease with increased distance from the epicenter or fault break.

ACTIVE FAULT - A fault that has moved in recent geologic time and which is likely to move again in the relatively near future. (For geologic purposes, there are no <u>precise</u> limits to recency of movement or probable future movement that define an "active fault." Definitions for planning purposes extend on the order of 10,000 years or more back and 100 years or more forward. The exact time limits for planning purposes are usually defined in relation to contemplated uses and structures.)

ALLUVIAL - Pertaining to or composed of alluvium, or deposited by a stream or running water. (AGI, 1972)

ALLUVIUM - A general term for clay, silt, sand, gravel or similar unconsolidated detrital material deposited during comparatively recent geologic time by a stream or other body of running water as a sorted or semisorted sediment in the bed of the stream or on its flood plain or delta, or as a cone or fan at the base of a mountain slope. (AGI, 1972)

AMPLIFICATION - Surface amplification is the increase of wave amplitude resulting from the change in physical properties in near-surface layers.

AMPLITUDE - The extent of the swing of a vibrating body on each side of the mean position. (Webster)

BLOCK SLIDE - A translational landslide in which the slide mass remains essentially in tact, moving outward and downward as a unit, most often along a pre-existing plane of weakness such as bedding, foliation, joints, faults, etc. (AGI, 1972)

COHESION - Shear strength in a sediment not related to interparticle friction. (AGI 1972)

COLLUVIUM - (a) A general term applied to any loose, heterogenous, and incoherent mass of soil, material, or rock fragments deposited chiefly by mass-wasting, usually at the base of a steep slope or cliff. (b) Alluvium deposited by unconcentrated surface runoff or sheet erosion, usually at the base of a slope (AGI, 1972).

COMPACTION - Reduction in bulk volume or thickness of, or the pore space within, a body of fine-grained sediments in response to the increasing weight of overlying material that is continually being deposited, or to the pressure resulting from earth movements within the crust. It is expressed as a decrease in porosity brought about by a tighter packing of the sediment particles (AGI, 1972).

CONSOLIDATED MATERIAL - Soil or rocks that have become firm as a result of compaction.

DAMPING - The resistance to vibration that causes a delay of motion with time or distance, e.g., the diminishing amplitude of an oscillation (AGI, 1972).

DEBRIS SLIDE - The rapid downward movement of predominantly unconsolidated and incoherent earth and debris in which the mass does not show backward rotation but slides or rolls forward, forming an irregular hummocky deposit which may resemble morainal topography. (Sharpe, C.F.S., Landslides and Related Phenomena, p. 74, 1938.)

DIFFERENTIAL SETTLEMENT - Nonuniform settlement; the uneven lowering of different parts of an engineering structure, often resulting in damage to the structure (AGI, 1972).

DIP-SLIP FAULT - A fracture along which the apparent movement has been predominantly parallel to the dip (from Gilluly, et. al.).

DISPLACEMENT (Geological) - The relative movement of the two sides of a fault, measured in any chosen direction; also, the specific amount of such movement. Displacement in an apparently lateral direction includes strike-slip and strike separation; displacement in an apparently vertical direction includes dip-slip and dip separation (AGI, 1972).

EIPCENTER - That point on the earth's surface which is directly above the focus of an earthquake (AGI, 1972).

FAULT - A surface or zone of rock fracture along which there has been displacement, from a few centimeters to a few kilometers in scale (AGI, 1972).

FAULT SURFACE - In a fault, the surface along which displacement has occurred (AGI, 1972).

FAULT SYSTEM - Two or more interconnecting fault sets (AGI, 1972).

FAULT ZONE - A fault zone is expressed as a zone of numerous small fractures or of breccia or fault gouge. A fault zone may be as wide as hundreds of meters (AGI, 1972).

FOCUS (Seism) - That point within the earth which is the center of an earthquake and the origin of its elastic waves. Syn: hypocenter; seismic focus; centrum (AGI 1972).

GROUND FAILURES - Include mudslide, landslide, liquefaction, subsidence.

GROUND RESPONSE - A general term referring to the response of earth materials to the passage of earthquake vibration. It may be expressed in general terms (maximum acceleration, dominant period, etc.) or as a ground-motion spectrum.

HISTORIC EARTHQUAKE - An earthquake which occurred within the recorded history of man. Approximately 200 years maximum in California for large earthquakes.

INACTIVE FAULT - A fault which shows no evidence of movement in recent geologic time and no evidence of potential movement in the relatively near future.

INTENSITY (earthquake) - A measure of the effects of an earthquake at a particular place on humans and/or structures. The intensity at a point depends not only upon the strength of the earthquake, or the earthquake magnitude, but also upon the distance from the point to the epicenter and the local geology at the point (AGI, 1972).

ISOSEISMAL LINE - A line connecting points on the earth's surface at which earthquake intensity is the same. It is usually a closed curve around the epicenter. Syn: isoseism, isoseimic line; isoseismal (AGI, 1972).

LIQUEFACTION - Change of water saturated cohesionless soil to liquid, usually from intense ground shaking; soil loses all strength.

MAGNITUDE (earthquake) - A measure of the strength of an earthquake or the strain energy released by it, as determined by seismographic observations. As defined by Richter, it is the logarithm, to the base 10, of the amplitude in microns of the largest trace deflection that would be observed on a standard torsion seismograph (static magnification = 2800; period = 0.8 sec: damping constant = 0.8) at a distance of 100 kilometers from the epicenter (AGI, 1972).

MAXIMUM CREDIBLE EARTHQUAKE - The maximum credible earthquake is the maximum earthquake that appears capable of occurring under the present known tectonic framework. It is a rational and believable event that is in accord with all known geologic and seismologic facts. In determining the maximum credible earthquake, little regard is given to its probability of occurrence, except that its likelihood of occurring is great enough to be of concern. It is conceivable that the maximum credible earthquake might be approached more frequently in one geologic environment than in another.

METASEDIMENTS - Partly metamorphosed sedimentary rocks (Stokes and Varnes, p. 91, 1955).

METAVOLCANICS - Partly metamorphosed volcanic rocks (Stokes and Varnes, p. 91, 1955).

MICROSEISMIC DATA - Used herein to describe instrumentally recorded earthquakes generally in the range of Richter magnitude 3.0 or less. (This use is consistent with the AGI definition of microseism and microseismometer, but is more restricted than their definition of microseismic data).

ROCKFALL - The relatively free falling of a newly detached segment of bedrock of any size from a cliff, steep slope, cave, or arch. (Sharpe, C.F.S., Landslides and Related Phenomena, p. 78, 1938.)

SEISMIC - Pertaining to or caused by earthquake.

SEISMIC HAZARDS - Hazards related to seismic or earthquake activity.

SEISMIC SEICHE - Standing waves set up on rivers, reservoirs, ponds and lakes at the time of passage of seismic waves from an earthquake (U. S. Geol. Survey Prof. Paper 544-E).

SHEAR - A strain resulting from stresses that cause or tend to cause contiguous parts of a body to slide relative to each other in a direction parallel to their plane of contact; specifically, the ratio of the relative displacement of these parts to the distance between them (AGI, 1972).

SHEAR WAVE OR S-WAVE - That type of seismic body wave which is propagated by a shearing motion of material so that there is oscillation perpendicular to the direction of propagation. It does not travel through liquids (AGI, 1972).

SLIP - On a fault, the actual relative displacement along the fault plane of two formerly adjacent points on either side of the fault. Slip is three dimensional, whereas separation is two dimensional (AGI, 1972).

STRIKE-SLIP FAULT - A fault, the actual movement of which is parallel to the strike (trend) of the fault (AGI, 1972).

SUBSIDENCE - A local mass movement that involves principally the gradual downward settling or sinking of the solid earth's surface with little or no horizontal motion and that does not occur along a free surface (not the result of a landslide or failure of a slope) (AGI, 1972).

SURFACE RUPTURES FROM FAULTING - Breaks in the ground surface resulting from fault movement.

TECTONIC - Of or pertaining to the forces involved in, or the resulting structures or features of, the upper part of the earth's crust (mod. from AGI, 1972).

TSUNAMIS - Earthquake-induced ocean waves, commonly referred to as tidal waves.

UNCONSOLIDATED MATERIAL - A sediment that is loosely arranged or unstratified or whose particles are not cemented together, occurring either at the surface or at depth (AGI, 1972).

WATER TABLE - The surface between the zone of saturation and the zone of aeration; that surface of a body unconfined ground water at which the pressure is equal to that of the atmosphere (AGI, 1972).

Table 1. MODIFIED MERCALLI INTENSITY SCALE OF 1931[1] (1956 VERSION)[2]

Masonry A, B, C, D. To avoid ambiguity of language, the quality of masonry, brick or otherwise, is specified by the following lettering.

Masonry A. Good workmanship, mortar, and design; reinforced, especially laterally, and bound together by using steel, concrete, etc.; designed to resist lateral forces.

Masonry B. Good workmanship and mortar; reinforced, but not designed in detail to resist lateral forces.

Masonry C. Ordinary workmanship and mortar; no extreme weaknesses like failing to tie in at corners, but neither reinforced nor designed against horizontal forces.

Masonry D. Weak materials, such as adobe; poor mortar; low standards of workmanship; weak horizontally.

I.	Not felt. Marginal and long-period effects of large earthquakes.
II.	Felt by persons at rest, on upper floors, or favorably placed.
III.	Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake.
IV.	Hanging objects swing. Vibration like passing of heavy trucks; or sensation of a jolt like a heavy ball striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV wooden walls and frame creak.
V.	Felt outdoors; direction estimated. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate.
VI.	Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Knickknacks, books, etc., off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster and masonry D cracked. Small bells ring (church, school). Trees, bushes shaken visibly, or heard to rustle.
VII.	Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices also unbraced parapets and architectural ornaments. Some cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.
VIII.	Steering of motor cars affected. Damage to masonry C; partial collapse. Some damage to masonry B; none to masonry A. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.
IX.	General panic. Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged. General damage to foundations. Frame structures, if not bolted, shifted off foundations. Frames racked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluviated areas sand and mud ejected, earthquake fountains, sand craters.
X.	Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly.
XI.	Rails bent greatly. Underground pipelines completely out of service.
XII.	Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air.

[1]Original 1931 version in Wood, H. O., and Neumann, F., 1931, Modified Mercalli intensity scale of 1931: *Seismological Society of America Bulletin*, v. 53, no. 5, p. 979-987.

[2]1956 version prepared by Charles F. Richter, *In Elementary Seismology*, 1958, p. 137-138, W. H. Freeman & Co.

COMPARISON OF MAGNITUDE AND INTENSITY

It is difficult to compare magnitude and intensity because intensity is linked with the particular ground and structural conditions of a given area, as well as distance from the earthquake epicenter, while magnitude is a measure of the energy released at the focus of the earthquake.

Richter Magnitude	Expected Modified Mercalli Max. Intensity (at epicenter)	
2	I-II	Usually detected only by instruments
3	III	Felt indoors
4	IV-V	Felt by most people; slight damage
5	VI-VII	Felt by all; many frightened and run outdoors; damage minor to moderate
6	VII-VIII	Everbody runs outdoors; damage moderate to major
7	IX-X	Major damage
8+	X-XII	Total and major damages

Source: Charles F. Richter, 1958, Elementary Seismology

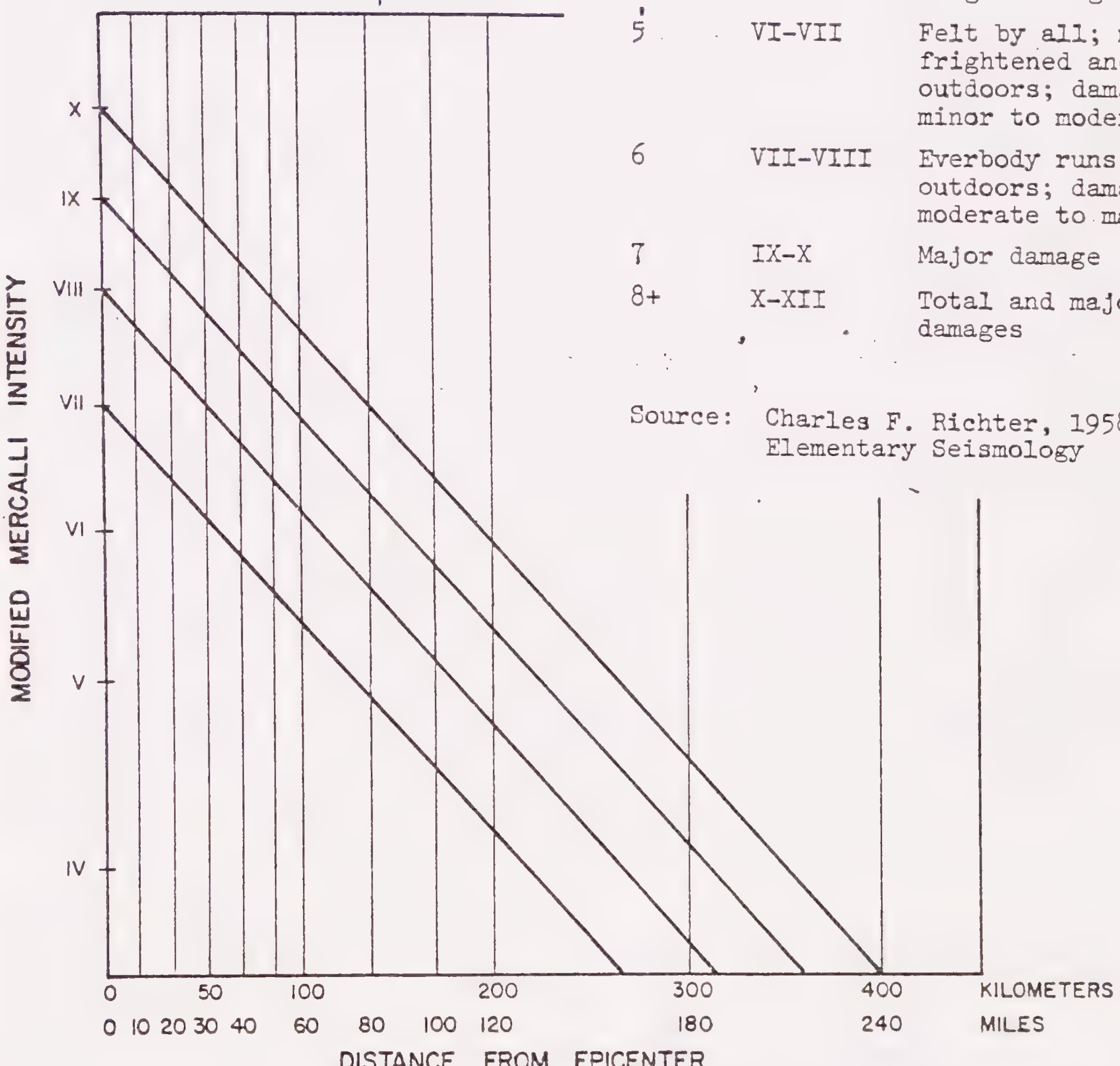

FIGURE 1

ATTENUATION OF MODIFIED MERCALLI INTENSITY WITH DISTANCE

SEISMIC SAFETY ELEMENT

BUTTE COUNTY GENERAL PLAN

PLANNING DEPARTMENT

REVISIONS

Source: Howell and Schult, 1975

■ DATA INVESTIGATION

LIMITATIONS

The seismic analysis for the Seismic Safety Element is based upon data obtained from geologic and seismic research. The analysis was prepared by CH2M HILL to aid in the Seismic Safety Element evaluation by Butte County and to assist in the planning for that County. The mapping is intended to indicate only general conditions and does not depict specific conditions at any particular site. The maps represent the opinions of the geologist as to the presence and character of materials and the possibility of hazards. The analysis was conducted in accordance with generally accepted engineering geology practices and makes no warranty either expressed or implied as to material included in the report.

The analysis of expected ground shaking was one of the primary objectives of this study. The extreme variation in geologic conditions and the lack of historical seismic information relating to ground shaking made the analysis extremely difficult. The Oroville earthquake of 1 August 1954 surprised the public and a majority of scientists. It was similar to the 1952 Bakersfield-Tehachapi earthquake and the 1971 San Fernando earthquake in that faults not then recognized as potentially active were, in fact, active and produced significant earthquakes.

It is a general assumption made in the selection of a design earthquake for an area that the seismic history of the area gives a reliable indication of future earthquake activity. Because the earthquake history of the western United States covers no more than 200 years and because the geologic processes that ultimately produce earthquakes cover a much longer period of time, it is apparent that there is insufficient data to make reliable estimates. Therefore, geologic data is used as well as seismic history in arriving at more realistic predictions of future seismic activity.

GENERAL METHOD

The investigation, conducted in November and December 1976, consisted primarily of:

- Compiling available published and unpublished geologic and seismic data relating to Butte County and surrounding areas
- Reviewing the geologic and seismic data
- Conducting engineering and geologic analyses of conditions in and around Butte County

- Compiling the above information on County base maps

- Preparing a report of findings

DATA COLLECTION

Data on basic geology and faults were obtained from various maps and reports published by the California Division of Mines and Geology. Seismic history and earthquake plots were obtained from the United States Department of Commerce, National Oceanic and Atmospheric Administration in Boulder, Colorado. Soil maps of Butte County were obtained from the United States Department of Agriculture, Soil Conservation Service, Report and General Soil Map of Butte County, California, published in 1967. A slope map of Butte County was prepared by the Butte County Planning Department in December 1976.

The principal sources of information concerning epicenter location and the areas affected were the U. S. Department of Commerce publication Earthquake History of the United States by Jerry L. Coffman and Carl A. von Hake, 1973, and the U. S. Department of Commerce Environmental Data Service Earthquake Plot of Northern California. General information regarding faulting and active faults was obtained from the publication by the California Division of Mines and Geology entitled Faults and Earthquakes in California, their 1975 Fault Map of California by Charles W. Jennings, and Special Report 124 Oroville, California Earthquake, 1 August 1975 by Roger Sherburne and Carl J. Hauge. The U. S. Department of Agriculture Soil Conservation Service Satellite Imagery Map of California, of November 1975, scale 1:500,000, was used to locate lineaments and possible faults in the Butte County area. The basic geology of the County was obtained from California Division of Mines and Geology, Geologic Map Series of California, scale 1:250,000, Chico Sheet and Westwood Sheet. General soils information for Butte County came from the U. S. Department of Agriculture Soil Conservation Service unpublished report and general soil map of Butte County dated February 1976. Additional geologic data were obtained from an unpublished geologic map of the Bangor quadrangle by Q. A. Aune and from the Official Map of the Special Studies Zone, Bangor quadrangle of January 1977.

The seismic and geologic data were analyzed using methods outlined in the 1973 report, A Map of Maximum Expected Bedrock Acceleration from Earthquakes in California, by Roger W. Greensfelder of the California Division of Mines and Geology, 1973, along with the reports State of the Art for Assessing Earthquake Hazards in the United States, and Report of Fault Assessing in Earthquake Engineering by Ellis L. Krinitzsay, published by the U. S. Army Engineers Waterways Experiment Station, Vicksburg, Mississippi, May 1974, and the 1972 paper

Accelerations in Rock from Earthquakes in the Western United States by P. B. Schnabel and H. B. Seed, both of the University of California.

STUDY MAPS

A geologic map of Butte County was prepared for analysis purposes using the Westwood and Chico sheets of the California Geologic Map Series. The location of faults was taken from the Fault Map of California by Charles W. Jennings and from the California Division of Mines and Geology, Oroville, California Earthquake Report. Lineaments or inferred fault locations were found in the U. S. Department of Agriculture Soil Conservation Service Satellite Imagery Map of California. Additional geologic information was obtained from the unpublished geologic maps of the Bangor quadrangle.

A map identifying the location of active or potentially active faults was prepared using the published maps of the California Division of Mines and Geology, along with the California Division of Mines and Geology Oroville, California Earthquake Report. Additional information regarding active faults and potentially active faults was obtained in verbal communication with personnel of the California Division of Mines and Geology.

Maps of slope stability, liquefaction potential, and differential subsidence problems were prepared from California Division of Mines and Geology geologic maps of the study area, U. S. Department of Agriculture Soil Conservation Service general soil maps of Butte County, and the rainfall intensity maps and slope maps of Butte County. Maps indicating the potential for ground shaking were prepared using information from the California Division of Mines and Geology and the Army Engineers Waterways Experiment Station.

Table 2. HISTORICAL EARTHQUAKES WITHIN 125 MILES OF CENTRAL BUTTE COUNTY

EARTHQUAKE DATA FILE

200-KM RADIUS AROUND 39.7N, 121.6W, FOR MAGNITUDES 5.0+. (FOR WEAVER)

SOURCE	YEAR	MO	DA	HR	MN	SEC	LAT	LONG	DEPTH (KM)	BODY	SURF.	OTHER	LOCAL	INT MAP	INT MAX	PHENOM DTSVNO	RN	CE	Q/S	MAR DG	DIST (KM)
G-R	1940	02	09	08	35	59.0	39.750N	121.250W	035			6.00PAS			VII		036	D		121 91	30
BRK	1942	12	03	09	44	42.0B	39.700N	119.300W					5.50MLBRK		VI		037	F	D	120 99	197
BRK	1942	12	17	15	07	43.05	38.870N	119.900W					5.10MLBRK		V		040	F	C	120 89	173
BRK	1943	03	30	21	37	22.00	39.430N	120.400W					5.30MLBRK				036	F	C	121 90	107
BRK	1946	07	07	06	55	15.0B	40.500N	121.500W					5.00MLBRK				036	F	B	157 01	89
G-R	1948	12	29	12	53	26.0	39.500N	120.100W				6.00PAS			VII		036	D		121 90	130
BRK	1950	03	20	15	22	17.0B	40.450N	121.470W				5.50PAS	5.50MLBRK		V		036	F	B	157 01	84
G-R	1950	12	14	13	24	19.0	40.100N	120.100W				5.60PAS		USE	VII		036	D		157 00	135
BRK	1952	05	09	15	31	32.0B	39.420N	119.780W				5.50PAS	5.10MLBRK		VI		037	D	C	120 99	159
BRK	1953	03	22	05	19	00.0P	38.320N	119.980W					5.00MLBRK		V		040	F	A	120 69	170
BRK	1953	09	26	03	34	29.5P	39.530N	119.980W				5.00PAS	5.30MLBRK	USE	VI		037	D	B	120 99	140
BRK	1955	10	24	04	10	44.0B	37.970N	122.050W					5.40MLBRK	USE	VII		039	D	A	121 72	196
BRK	1959	04	01	18	18	30.0P	39.720N	120.200W					5.60MLBRK	USE	VII		036	D	D	121 90	120
BRK	1962	06	06	17	50	26.0P	39.770N	123.320W					5.20MLBRK	USE	VII		035	D	B	121 93	163
BRK	1966	09	12	16	41	01.1P	39.420N	120.150W		5.70MB		6.38PAS	6.00MLBRK	USE	VII		036	D	095	121 90	128
BRK	1966	09	12	17	20	11.3P	39.420N	120.150W		4.80MB			5.30MLBRK				036	F	017	121 90	126
BRK	1968	04	29	00	21	36.6B	39.540N	122.020W		5.00MB			4.70MLBRK				036	F	060	121 92	40
BRK	1969	10	02	04	56	46.5P	38.470N	122.690W		5.20MB	4.8SH		5.60MLBRK		VIII		036	D	C	121 82	165
BRK	1969	10	02	06	19	57.0P	38.460N	122.690W		5.10MB			5.70MLBRK				036	F	080	121 82	166
GS	1975	08	01	20	20	04.85	39.439N	121.528W	008	4.4 MB	5.7SZ		4.50MLBRK				036	F	48	121 91	29
GS	1975	08	01	20	20	12.95	39.439N	121.528W	015	5.8 MB	5.6SZ		5.70MLBRK		VII F		036	D	221	121 91	29
GS	1975	08	01	21	21	53.7P	39.442N	121.528W	008	5.3 MB			4.10MLBRK		IV		036	F	15	121 91	29
GS	1975	08	02	20	22	16.3P	39.445N	121.463W	004	5.3 MB	4.5SZ		5.10MLBRK				036	F	129	121 91	30
GS	1975	08	02	20	59	02.7*	39.406N	121.711W	005G	5.2 MB	4.7SZ	.	5.10MLBRK				036	D	124	121 91	34
GS	1975	08	03	01	03	05.8P	39.488N	121.518W	008	5.0 MB			4.60MLBRK				036	F	37	121 91	24
GS	1975	08	06	03	52	29.95	39.479N	121.524W	007	5.1 MB	4.0SZ		4.70MLBRK		IV		036	F	111	121 91	25
GS	1975	08	06	16	41	52.1P	39.497N	121.520W	008	5.2 MB			3.60MLBRK				036		18	121 91	23
GS	1975	08	08	07	00	57.16	39.502N	121.512W	008	5.0 MB			4.90MLBRK				036	F	73	121 91	23
GS	1975	09	27	22	34	38.1B	39.512N	121.537W	008	5.3 MB	3.5SZ		4.60MLBRK		IV		036	F	67	121 91	21

THIS RUN CONTAINS 29 HITS

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76/11/18 PAGE 1

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